Morphing Design for Socially Interactive Autonomous Car by Multi-Material 3D-Printing

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ABSTRACT

An autonomous car, also known as a robot car, self-driving car, is a vehicle that is capable of sensing its environment and moving with little or no human control. In most cases today, a driver can switch “driving mode” of his/her car between manual and autonomous. However, while the mode can be smartly changed, it is not able to show the current driving mode to nearby pedestrians. This might become a source of anxieties for many ordinary people living in the era of autonomous car. To overcome this issue, we propose to create a car with new expressive functions, and make it communicable and interactive. Unlike conventional approaches which use displays and LEDs, our approach is to develop 3D shape-transforming, morphable body of a car by using multi-material 3D-printing. Our first trial with printed soft membranes was successful in representing three different modes of a car seamlessly. In this paper, we introduce our concept, core technologies and implementations, and discuss further possibilities and future works.

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KEYWORDS
3d printing; Additive Manufacturing; Autonomous Car; Morphing Design

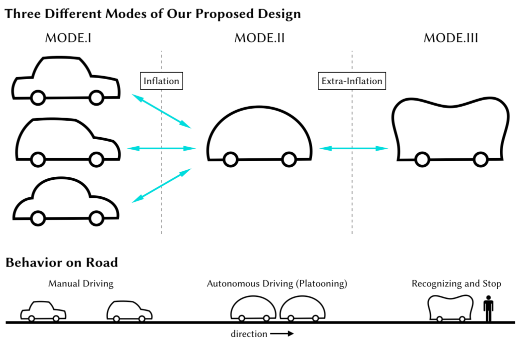

Figure 1: Three Different Modes of Our Proposed Design

1 Introduction

“Autonomous Car” has received a great amount of attention from industries [1, 2] and many reports on test driving in urban areas have been published in recent years. Especially driving in urban areas today, a driver is required to switch “driving mode” of his/her car between manual and autonomous. In the field of interaction design, interaction between a “driver” and an “autonomous car” is not an unexplored issue [3]. However, there are only a few studies on interaction between a “pedestrian” and an “autonomous car”. There is an interaction-design research between an autonomous car and pedestrians only when a car is driving in autonomous mode [4]. That ignored several different modes that a car and a driver should switch.

In this paper, we focus on new expressive functions for autonomous cars to show its current mode to pedestrians. Unlike conventional approaches which use displays and LEDs, our approach is to develop 3D-shape transforming, morphable body of a car by using multi material 3D printing.

In the field of 3D printing, car design is recognized as one of those important application domains [5-7]. Due to recent developments of large-scale 3D printing technologies, it’s not difficult to 3D-print a body of a car. However, most of conventional 3D-printed plastic cars are still hard and static. They don’t have enough dynamic transforming functions and softness which could address people’s concerns.

2 Basic Concept

Figure.1 shows our concept of socially interactive morphable autonomous car. This car should be capable of telling three different modes of an autonomous car, such as “normal manual driving” (MODE.I), “normal autonomous driving” (MODE.II) and “autonomous driving which recognizes pedestrians walking around” (MODE.III) .

First, we propose a shape of “normal manual driving mode (MODE.I) ” to be similar to the traditional shape of a car, and a shape of “normal autonomous driving mode (MODE.II) ” to be stubby to make it recognizable to pedestrians.

Next, we think the third mode, “autonomous driving which recognizes pedestrians walking around (MODE.III) ” is the most important. In general, one feels at ease when he or she sees that other people recognize him or her by making face expressions and gestures. This is the fundamental social interaction in our everyday lives. We believe an autonomous car should have the same function. In our proposal, the shape should be like an animal or a pet when a car finds pedestrians walking around, and the car itself gradually slow down.

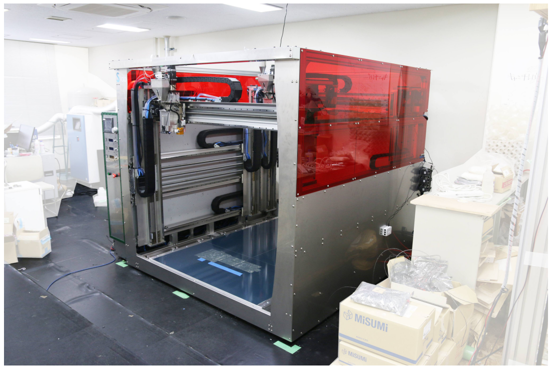

Figure 2: Our Large-Scale 3D Printer called "ArchiFab II"

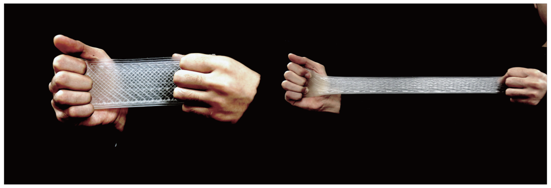

Figure 3: Printed stretchable sheet

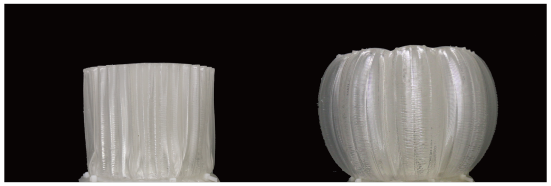

Figure 5: Inflatable lamp shade for testing basic material performance

3 Large-Scale Multi Material 3D Printing

We use our original large scale FDM 3D-printing machine which covers 1m*1m*1m with three big extruder heads (Figure.2). Since a big extruder was originally used for plastic injection, this extruder allows us to use "pellets" type of various materials, so we can apply extremely soft and flexible materials. Three extruders can work with different materials independently, so we realize multi-material 3D printing.

We apply elastomer-based special soft pellets and print layered sheets. Figure.3 show our achievements on a printed stretchable sheet.

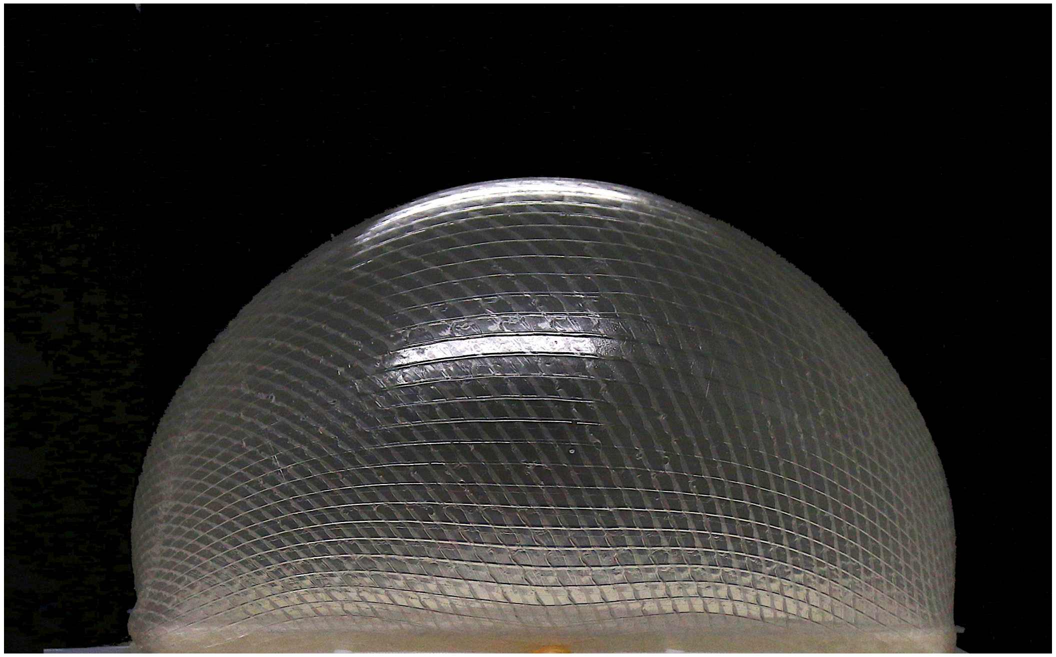

Figure 4: Inflation of printed soft membrane

Moreover, when we pump air into a sheet, a sheet can work as a membrane and it's easy to be inflated (Figure.4). Figure.5 shows our inflatable lampshade for the basic shape changing test.

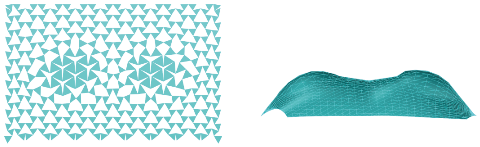

Figure 7: Input mesh and calculated pattern

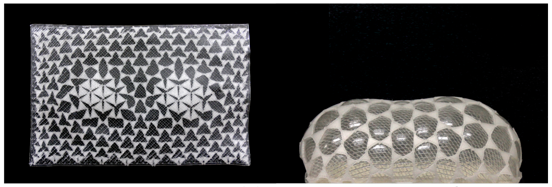

Figure 8: Programmable Auxetic Pattern from 2D sheet to target 3D Shape

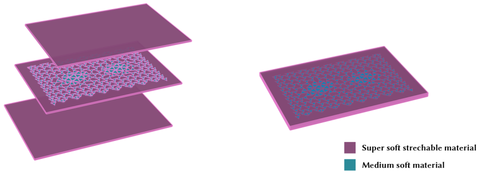

Figure 9: Sandwich structure with multi material printing

4 Morphing Design

As we introduced in Figure.1, we tried to make the three-levels-shape-changing mechanism by making use of soft material printing.

First, the shape of MODE.I is printed with hard plastic (ABS) shown in Figure.6. About a shape of a traditional car, we use the open-sourced 3D data of HONDA classic car NSX[8].

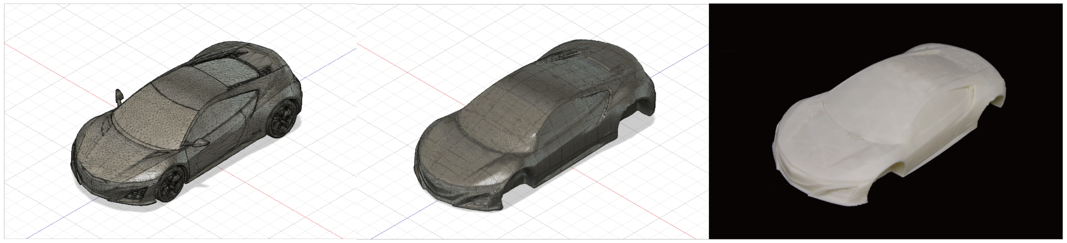

Figure 6: Printing “normal manual driving mode”

Second, we apply a special technique called “programmable auxetic pattern” [9] to realize two different shapes of MODE.II and MODE.III into one membrane.

“Programmable auxetic pattern” is a way to “program” a 3D target shape into a 2D sheet by computed geometric patterns. We adopted this technique to morphing design.

To exaggerate the power of auxetic pattern morphing, we created sandwich structure shown in Figure.9. The first and the third layers were printed with special soft and stretchable material, while we inserted auxetic geometries with medium soft material in the second layer. Therefore, in this 1/10 scale model, when we pumped air into a sheet at a pressure of about 0.3MPa, membranes were gradually inflated into the stubby target shape (MODE.II). When we pumped air into a sheet at pressure of about 1.7MPa, finally it became a target 3D animal shape (MODE.III).

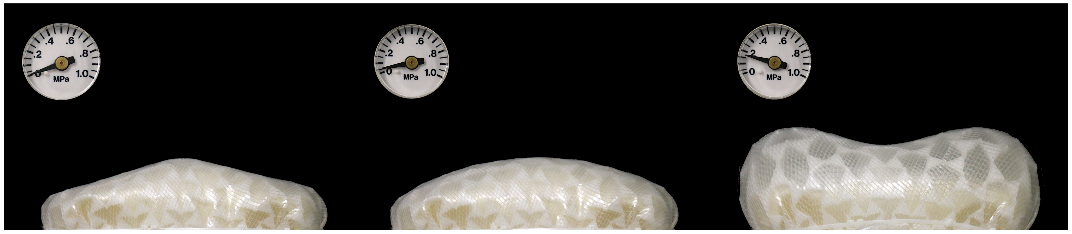

Figure 10: Three Different shape of a morphed car

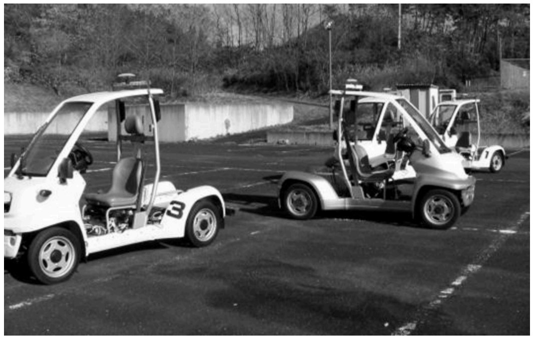

Figure 11: 1/1 vehicle platform COMS [10]

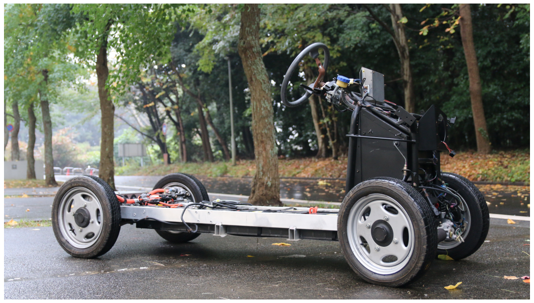

Figure 12: COMS with exterior removed

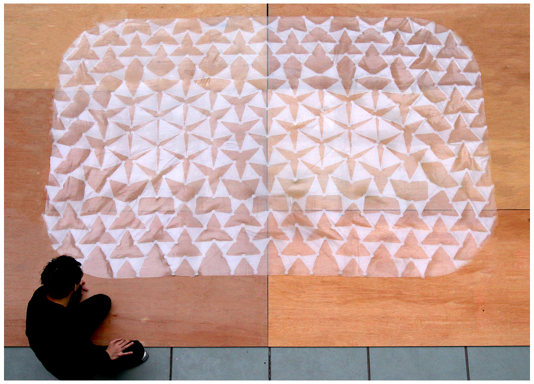

Figure 13: Printed Large sheet for 1/1 mock-up

5 1/1 Working Prototype

We are in the process of developing a 1/1 scale prototype. COMS [10] is an easy-to-customize electric vehicle platform for one driver. We printed a 3m*2m large sheet with programmable auxetic pattern (Figure.13). When we pump air, the result is shown in Figure.14.

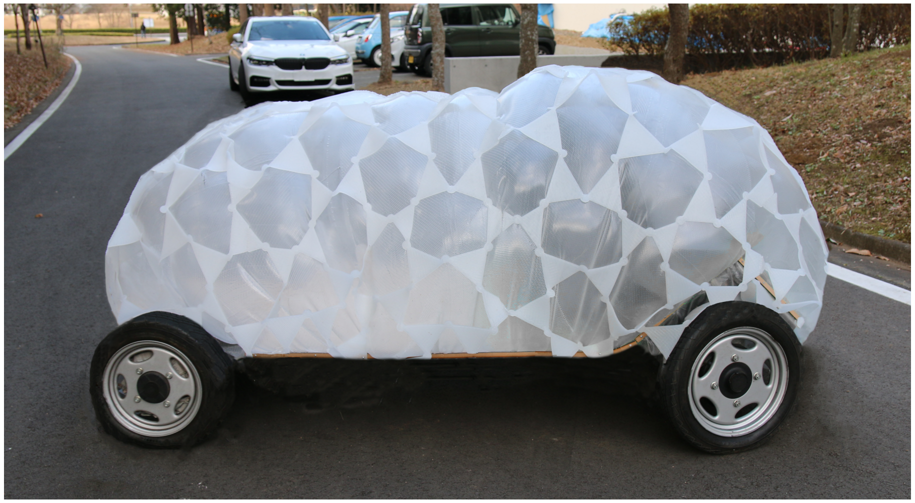

Figure 14: 1/1 mock-up

6 Conclusions and Future Works

We showed an approach to create an autonomous car with new expressive functions and make it communicable and interactive. Our approach is to develop 3D-shape changing, morphable body of a car by using multi-material 3D-printing. Our first trial with printed soft and inflatable membranes was successful in representing three different modes of a car. We are going to test our 1/1 prototype and obtain user (pedestrian) responses in the real urban contexts.

We believe autonomous cars should be socially interactive machines in a fundamental manner. In that sense, our next target is designing interactions between an autonomous car and its surroundings and deep contexts. For example, morphing designs according to scenes and seasons are one of our future works.

We also believe that the key technology for performative morphing design is applying special materials to 3D-Printing [11]. In this research, we adopted three different materials (hard ABS, special soft, medium soft). We keep working on exploring new materials and its new hybrid combinations with other materials by using the multi-heads 3D printer.

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